Appendix A:

Description and Results of Acoustical Range Studies and Experiments

SPORTING CLAY RANGE STUDY

Method

1. Acoustical measurements were conducted at Location R1, R2, and R3 of shotguns fired at all 27 Sporting Clay Range stations on June 3, 2008 and June 10, 2008 to identify the extent to which the sounds exceed the ambient sound levels at these locations, document differences in sound level with direction of fire both horizontally and vertically, quantify the effects of the existing shed enclosures, and develop sound reduction strategies for the individual stations.

2. Figure A-1 contains an aerial map showing the location of the 27 Sporting Clay Range stations, labeled A1, A2, A3, and B through Y. Three shooters were used for the study. Each shooter had a 12 Gauge Shotgun with a 1 oz, 7-1/2 shot, 2-3/4" long, 2.75 dram Estate Super Sport Competition Target Load.

3. Working sequentially in a counter-clockwise direction from Station A1 to Station Y, the first shooter would shoot four rounds, than the second shooter, and then the third shooter. All three shooters would then move to the next three stations and repeat the drill.

4. The four rounds fired at each station consisted of one shot to the left with the gun relatively horizontal and parallel with the ground, an approximate three second pause, one shot to the left with the gun pointed up on a 30 to 40 degree angle above horizontal, a pause of approximately 9 to 12 seconds to reload, one shot to the right with the gun pointed up on a 30 to 40 degree angle above horizontal, an approximate three second pause, and one shot to the right with the gun relatively horizontal and parallel with the ground. The shots to the left and to the right were approximately 45 degrees off-axis of the centerline of the shed.

5. The same battery of shots were repeated with the shooter outside the shed enclosure at stations C, F, L, P, S, and V to determine the effects of the existing shed enclosures on sounds from the shotguns propagating long distances to receiver locations R1, R2, and R3. A separate insertion loss experiment for the shed enclosures taken at closer distances (less than 500 ft) is described in a later section in Appendix A.

6. The exact times at which the shots were fired were noted by the Consultant stationed at the Range. The meters were synchronized and the sound level of the shots were identified in the data by comparing the times at which the shots occurred and the time on the meter, in addition to the notes taken by the Consultants at the receiver positions.

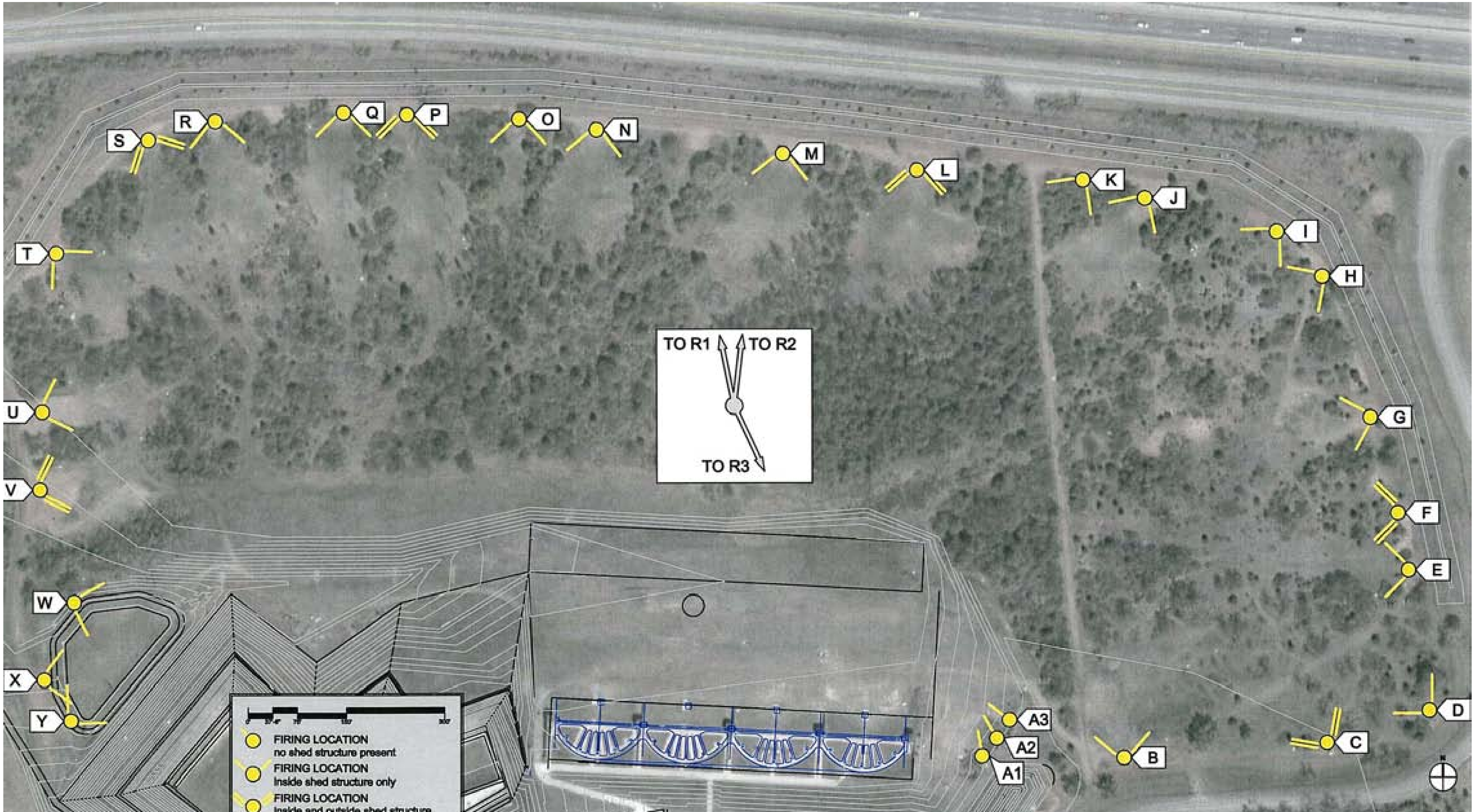

Figure A-1. Aerial map showing the location of the 27 Sporting Clay Range shooting stations. Acoustical measurements were made with shooters at each station.

Measurement Results

General Comments

1. Table B-1 in Appendix B contains a tabular summary of the Sporting Clay Range Study sound level data. Where shots were inaudible and/or not identifiable in the data, the cell is marked with a "-----". The table shows that many of the gunshots were not audible or identifiable in the data at the three receiver locations.

2. In general, only sources that were pointed in the general direction of the receivers were audible and measurable.

3. Graphs of the 100-msec measurements made during the Sporting Clay Range Studies are included in Appendix C for each receiver location. The periods of time when the guns were fired from each group of three stations are shaded on the graphs.

4. Weather data for the two dates indicates that wind was coming out of the north/northeast on June 3, 2008, and out of the south/southwest on June 10, 2008, which may explain the increase in sound levels at Location R2, which would have been downwind relative to the Ranges, on June 10, 2008, and the decrease in sound level at R3, which would have been upwind relative to the Ranges on June 10, 2008. Location R1, being somewhat east of the site, as well as north, would have benefitted more from the winds from the east/northeast on June 3, 2008, and correspondingly had higher sound levels than on June 10, 2008, when the wind was out of the south/southwest. There did not appear to be a significant temperature inversion on either day.

5. **Effects of the horizontal direction of the shotguns on distant receiver sound levels.** Sound level differences from 0 dB to 13 dB were obtained between shots that were fired to the left and shots that were fired to the right. The lesser differences occurred where the centerline of the station in the direction of fire was more in line with the receiver location, such as at station S, which points directly towards receiver Location R3. Greater differences occur where the receiver location is much more off axis, and only one of the two directions fired is in line with the receiver location, such as at location O, where only shots fired to the left (southeast) are in the general direction of receiver Location R3.

6. **Effects of the vertical angle of the shotguns on distant receiver sound levels.** The difference in sound levels measured at receiver Locations R1, R2, and R3, between shots fired level with the ground and shots fired more vertically was generally +/- 1 to 3 dB, with occasional differences as high as +/- 6 to 7 dB, with the sound level of the level shot actually exceeding the sound level of the more vertical shot on more occasions (33 vs. 25). These differences are likely to be within the range of variability that could be attributable to the effects atmospheric conditions would have on individual gunshots traveling distances of over a mile. Therefore, it appears that the vertical position of the shotgun relative to the ground, within the range of angles one would use for sporting clay target shooting, does not have a significant effect on the level of the gunshot sounds measured at large distances (over 1 mile) from the shooter.

7. **Changing the target presentation without changing the shed location or orientation is not**

likely to result in significant reductions in sounds propagated to residential receivers to the north or south of the Range. Reductions in sound experienced at one residence by changing the horizontal location of the target will just result in increases at another residence that will be more in the direct line of fire. It is not until the shots are fired more in an east or west direction that the sound levels to receivers on the north and south sides will experience noticeable reductions in sound levels.

8. **The effects of the sporting clay partial shed enclosures on receiver sound levels.** Sound levels measured at Locations R1, R2, and R3 in directions that were behind specific sheds were inaudible and not measurable in the data, whether the shooter was inside the shed or outside the shed. Therefore, the extent to which the sheds provide insertion loss in the direction behind the shooter at large distances (over 7,000 ft) could not be determined. The results of the insertion loss experiments on the sheds indicate that at shorter distances (75 ft), the sheds provide an 18 dBA insertion loss.

   Sound levels measured at Locations R1, R2, and R3 when in the general direction of gunfire from specific sheds were between -2 and +4 dB when the shooter was outside the shed compared to when the shooter was inside the shed. This is likely to be within the range of variability that could be attributable to the effects atmospheric conditions would have on individual gunshots traveling distances of over a mile, and therefore it appears that the sheds may not have any significant effect on the level of sounds propagated in the forward direction relative to the shooter at large distances. This is confirmed by the insertion loss experiment on the shed, which showed changes of 0 to 1 dB in the direction of the line of gunfire, which is within the typical range of variability of shotgun sound levels from one shot to the next.

<u>Location R1</u>

1. The ambient sound level at Location R1 at that time of the Sporting Clay Range Study was generally in the 41 to 47 dBA range on June 3, 2008 and in the 45 to 50 dBA range on June 10, 2008. Identifiable sounds consisted primarily of birds chirping, distant traffic sounds, occasional planes overhead, and wind in the trees, with elevated distant traffic sounds on June 10, 2008 due to the wet roads from a recent storm.

2. Gunshots were audible and measurable at receiver Location R1 only when stations A1, A2, A3, B, C, D, and E were used on June 3, 2008, and only when A1, A2, A3, B, C and D were used on June 10, 2008. These stations primarily face to the north or northwest.

3. Sound levels from guns fired during the Sporting Clay Range studies were measured at levels of 47 to 60 dBA at location R1. This exceeds the ambient sound levels by as much as 5 to 15 dB, which would be perceived by people with normal hearing sensitivities as plainly audible to three times as loud as the ambient.

<u>Location R2</u>

1. The ambient sound level at Location R2 at the time of the Sporting Clay Range Study was generally in the 40 to 50 dBA range on June 3, 2008 and in the 43 to 53 dBA range on June 10,

2008. Identifiable sounds consisted primarily of birds chirping, distant traffic sounds, occasional planes overhead, and wind in the trees, with elevated distant traffic sounds on June 10, 2008 due to the wet roads from a recent storm.

2. Gunshots were audible and measurable at receiver Location R2 only when stations A1, A3, and B, were used on June 3, 2008, and only when stations A1, A2, A3, B and C were used on June 10, 2008. These stations primarily face to the north or northwest.

3. Sound levels from guns fired during the Sporting Clay Range studies were measured at levels of 44 to 64 dBA at location R2. This exceeds the ambient sound levels by as much as 5 to 15 dB, which would be perceived by people with normal hearing sensitivities as plainly audible to three times as loud as the ambient.

<u>Location R3</u>

1. The ambient sound level at Location R3 at that time of the Sporting Clay Range Study was generally in the 38 to 45 dBA range on June 3, 2008 and in the 40 to 45 dBA range on June 10, 2008. Identifiable sounds consisted primarily of birds chirping, distant highway sound, planes passing overhead, cars passing on nearby Dixboro Road.

2. Gunshots were audible and measurable at receiver Location R3 only when stations J through T were used on June 3, 2008, and only when stations L, M, and O through T were used on June 10, 2008, with the exception of one gunshot at station U audible when firing up and towards the southeast. These stations primarily face to the south or south east.

3. Sound levels from guns fired during the Sporting Clay Range studies were measured at levels of 46 to 61 dBA at location R3. This exceeds the ambient sound levels by as much as 10 to 20 dB, which would be perceived by people with normal hearing sensitivities as two to four times as loud as the ambient.

Sound Reduction Studies

1. Several sound reduction strategies were considered to reduce gunfire sounds from the Sporting Clay Range. The first was to consider re-orienting all of the shooters on the north side so that they were oriented back to back and facing east and west along a road that runs north south through the center of the north half of the site. While this provided the needed 300 yard safe zone between sporting clay shooters facing each other, it resulted in an unsafe distance between the Trap and Skeet Range shooters and the sporting clay shooters and therefore was not viable.

2. A computer model was then developed to study the effects of depressing the north side of the Sporting Clay Range by 20 feet and building up a 40 ft berm between the north side shooters and the Trap. The Computer Model was run in Cadna/A software using the modeling capabilities of the software to create a detailed model of topography, ground effects, reflections from buildings, berms, walls and other details of the site to study gunfire sound levels at critical locations. Sound power level values of the firearms used in the Cadna/A model were derived from SEL values, provided by SARNAM, for the firearms at 1 meter. SEL values are provided by SARNAM for

azimuth angles every 5˚ from 0˚ to 180˚. These values were converted to Leq values using a 0.5 msec event time to derive peak values and 0.125 msec event time to derive fast average values. The Leq's were averaged and converted to a sound power level by multiplying the average Leq value by the area of a hemisphere with 1 meter radius around the gun. These sound power levels, along with the directivity index derived from taking the difference between the spatially averaged Leq's and the directional Leq's, were inserted into the Cadna/A model.

3. Two models were constructed to study the effects of constructing a berm in front of the Sporting Clay Stations at the north of the Island Lake Shooting Range on sounds of gunshots propagating to critical areas to the south. The first model (Model A - existing, shown in Figure A-2) consisted of the existing shooting range with 10 sources at the north Sporting Clay Stations J through S. The second model (Model B - with Berm, shown in Figure A-3) consisted of depressing the north side of the Sporting Clay Range by 20 feet and building up a 40 ft berm between the north side shooters and the Trap approximately 100 yards from Sporting Clay Station K though Q. Station S was relocated further southwest and oriented toward the east; and Station J was relocated further southeast and oriented toward the west.

4. Instantaneous sound levels at points of interest and sound contours were produced for Model A - Existing and Model B - with Berm, with all the northern Sporting Clay Stations being used simultaneously. The differences between the two computer models are summarized in Table A-1 and shown in Figure A-3.

Table A-1. Summary of computer model sound level differences attributed to the effects of a 40 ft tall berm located in front of the Northern Sporting Clay Stations.

Location	Difference in Short Term Sound Levels between Model A - Existing, and Model B - with Berm
R3	- 3 dB with berm
R7	- 3 dB with berm

5. The results show that the 40ft berm provides only a 3 dB reduction in sound levels at receiver locations R3 and R7 to the south of the Island Lake Shooting Range. A berm modeled at 70 ft was only able to produce a 5 dB reduction in sound. Given the minimal improvement in sound levels and cost of the earthwork to construct berms of this size, these options may not be considered cost effective.

6. A similar study using berms on the north side to reduce sounds from the south side stations yielded similar results.

7. The only options remaining to reduce the sounds from the Sporting Clay Range stations are to eliminate or relocate specific stations on the north and south sides or to build a full building enclosure over the Sporting Clay Range. Please refer to the main body of the report for more on this subject, including specific recommendations for relocating and eliminating the stations.

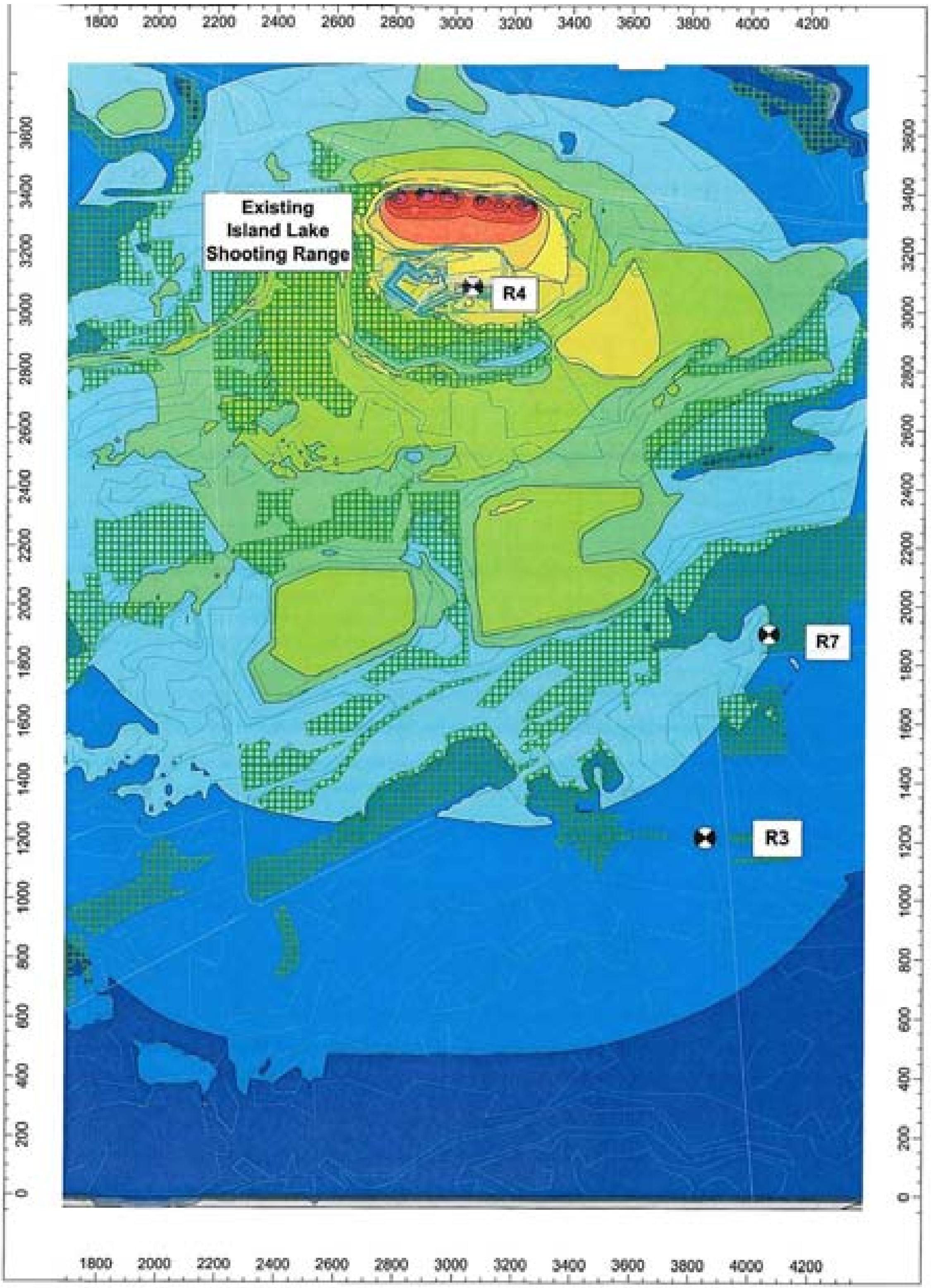

Figure A-2. Computer model of existing range with 10 shooters firing guns from the northern sporting clay stations.

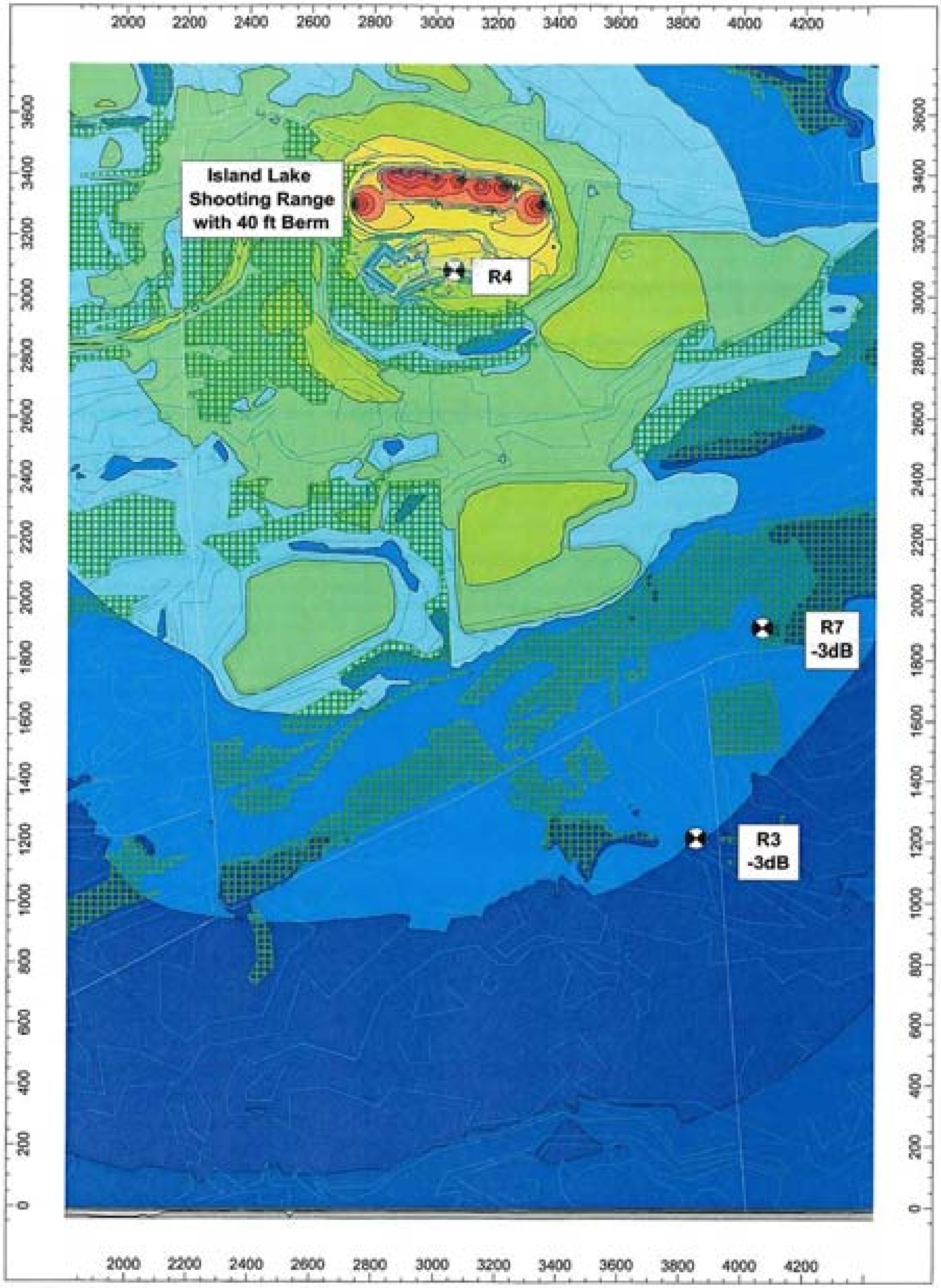

Figure A-3. Computer model of the range with a 40 ft berm with 10 shooters firing guns from the northern sporting clay stations showing the decrease in sound level in the direction of gunfire.

TRAP AND SKEET RANGE STUDY

Method

1. On June 3, 2008, acoustical measurements were made of a single shooter at various positions in Trap and Skeet Range 2, which is the second range from the west.

2. The shooter was using a 12 Gauge Shotgun with a 1 oz, 7-1/2 shot, 2-3/4" long, 2.75 dram Estate Super Sport Competition Target Load.

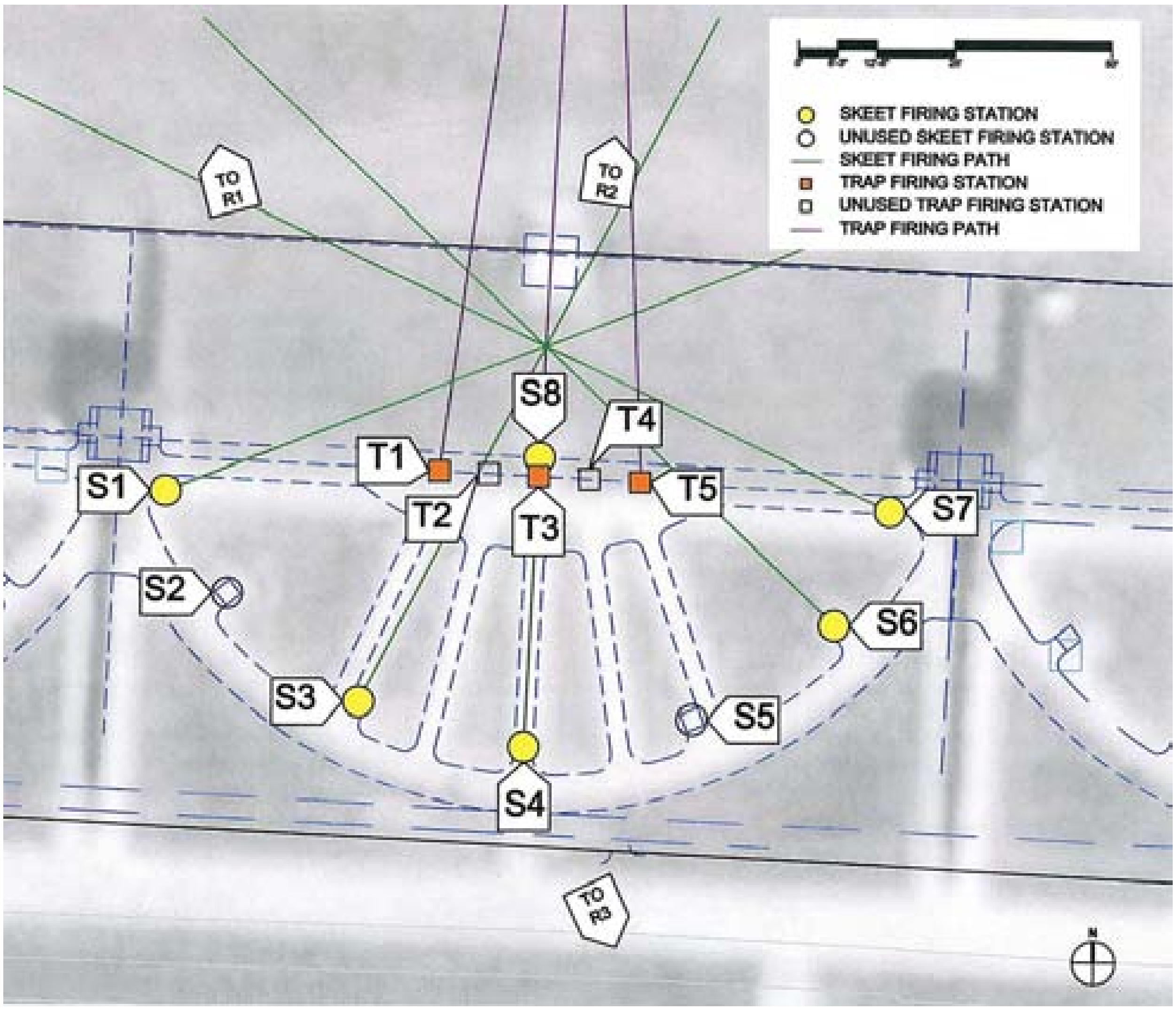

Figure A-4. Aerial map and plan of the Trap and Skeet Range showing the shooter positions used for the study and the general direction of fire for each position.

3. Please refer to Figure A-4 for an aerial map and plan of Trap and Skeet Range 2 showing the firing positions. Two shots were fired, in order, from position S1, S3, S4, S6, S7, S8, T1, T3, and T5, with a spacing of approximately 4 to 5 seconds between the two shots at each position, and approximately 20 seconds between the last shot of one position and the first shot at the next

position. The firearm was aimed at a similar angle in plan to the orientation suggested by the pavement of the shooting position, at a middle to low trajectory.

4. The exact times at which the shots were fired were noted by the Consultant stationed at the Range. The meters were synchronized and the sound level of the shots were identified in the data by comparing the times at which the shots occurred and the time on the meter, in addition to the notes taken by the Consultants at the receiver positions.

Measurement Results

General Comments

1. Table B-2 in Appendix B contains a tabular summary of the Trap and Skeet Range Study sound level data. Where shots were inaudible and/or not identifiable in the data, the cell is marked with a "-----". The table shows that sounds from the Trap and Skeet Range were only audible and identifiable in the data at the northern receiver locations.

2. Graphs of the 100-msec measurements made during the Trap and Skeet Range Study are included in Appendix C for each receiver location. The periods of time when the guns were fired from each range use type (Skeet versus Trap) are shaded on the graphs.

Location R1

1. The ambient sound level at Location R1 at that time of the Trap and Skeet Range Study was generally in the 39 to 45 dBA range. Identifiable sounds consisted primarily of birds chirping, distant traffic sounds, occasional planes overhead, and wind in the trees.

2. Sounds from the Skeet shooting exercises were mostly in the 44 to 49 dBA range at Location R1, with one gunshot as high as 54 dBA.

3. Sounds from Trap shooting exercises were in the 44 to 51 dBA range, with the loudest sound coming from Location T5, which is pointed more in the general direction of receiver Location R1 than the other Trap positions. These sounds were generally 2 to 5 dB above the ambient, which is a barely audible to plainly audible difference to people with normal hearing sensitivities.

Location R2

1. The ambient sound level at Location R2 at the time of the Trap and Skeet Range Study was generally in the 38 to 48 dBA range. Identifiable sounds consisted primarily of birds chirping, distant traffic sound, cars passing on Labidie Road, an ambulance in the distance, a helicopter in the distance, and a jogger passing on the road.

2. Sounds from the Skeet shooting exercises were not audible or identifiable in the data in the presence of the ambient sounds.

3. Sounds from the Trap shooting exercises were in the 43 to 49 dBA range, with most sounds faintly audible and several not identifiable in the data in the presence of the ambient sounds, which included a helicopter in the distance during the first set of Trap measurements.

Location R3

1. The ambient sound level at Location R3 at the time of the Trap and Skeet Range Study was generally in the 33 to 43 dBA range. Identifiable sounds consisted primarily of cars and trucks on Dixboro Road, distant traffic sound, planes in the distance, and road construction to the east.

2. Sounds from the Trap and Skeet Range exercises were not audible at Location R3 in the presence of the ambient sound, nor could they be identified in the measurement data.

Analysis/Conclusions

1. The data show that during the relatively neutral atmospheric conditions that occurred at the time of the measurements, sounds from firearms fired on the Ranges were plainly audible at Location R1 at levels that typically exceeded the ambient sound level by 5 to 10 dB, and occasionally by as much as 10 to 15 dB, depending on the direction in which the gun was fired. Under acoustically adverse atmospheric conditions, these sounds could increase by as much as 10 dB or more.

2. Sounds from the Trap and Skeet Range activities were not audible at Location R3 in the presence of a relatively low ambient sound level of 33 to 43 dBA. This is due to the directionality of sound from the guns, in which sound in the direction of fire are approximately 20 dB higher than sound in the direction opposite of fire, and the presence of the 20 ft high berm behind the shooters, which is providing an additional 7 to 10 dB of sound reduction. Based on these factors, it is estimated that sounds attributable to the Trap and Skeet Range gunfire would be approximately 25 to 30 dBA or less at Location R3, which explains why they were not audible.

3. Under acoustically adverse weather conditions (wind blowing to the north, low cloud cover, etc.), it is possible that sounds from the Trap and Skeet Range would reach levels as high as 64 dBA at Location R1 and 58 dBA at Location R2. These sounds would exceed the typical ambient sound level of 38 to 48 dBA at Locations R1 and R2 by as much as 15 to 25 dB, which would generally be perceived as three to five times louder by people with normal hearing sensitivities.

Recommendations

1. A computer model was constructed similar to the one generated for the Sporting Clay Range to determine the effectiveness of increasing the berm height downstream of the Trap and Skeet Range from 10 ft to 30 ft. The results showed a net reduction in sound level of 1 dB at critical receiver locations to the north, which would be barely heard if at all by people of normal sensitivities and therefore may be considered impractical to construct.

2. A full building enclosure of the Trap and Skeet ranges would be required to reduce the sounds from the Trap and Skeet Range to the vicinity of the ambient sound levels at residential receivers

to the north under all virtually all weather conditions.

RIFLE AND PISTOL RANGE STUDY

Method

1. Acoustical measurements were conducted on June 3, 2008 in each of the three Rifle and Pistol Ranges to document the sound levels of the Ranges at receiver Locations R1, R2, and R3, to identify the extent to which the individual ranges contribute to these levels, and to document the differences in levels associated with a range of typical firearms used on the ranges, including rifles, shotguns, and handguns.

2. For the 100-Yard Range measurements, the shooters were stationed in Lane 4, Lane 11, and Lane 17. For the 50-Yard Range measurements, the shooters were stationed in Lane 21, Lane 26, and Lane 30. For the 25-Yard Range measurements, the shooters were stationed in Lane 31, Lane 35, and Lane 40. Shooters were sitting down for all shots with the gun resting on the table.

3. Five firearms were fired. They were:
    1. .308 Caliber Springfield M1A Semi-Automatic Rifle with Federal American Eagle 150 grain Full Metal Jacket ammunition
    2. .308 Caliber Remington Bolt-Action Rifle with Federal American Eagle 150 grain Full Metal Jacket ammunition
    3. .223 Caliber Colt AR-15 Semi-Automatic Rifle with Federal Tactical 55 grain ammunition
    4. 12 Gauge Remington Police 870 Shotgun with Federal 12 ga, 1 oz solid lead, 2-3/4" long slugs
    5. 40 Caliber Sigsauer Semi-Automatic Pistol with Federal 180 grain Full Metal Jacket ammunition

3. Each shooter had a .308 Semi-Automatic Rifle, a .12 Gauge Shotgun, and a 40 Caliber Handgun. The “middle” shooter of the three at each Range (Lane 11, Lane 26, and Lane 35) had the only .308 Caliber Bolt-Action Rifle and .223 Caliber Semi-Automatic.

4. All firearms were fired two times for a total of 22 shots fired. Approximately 2 to 3 seconds were allowed between shots and approximately 8 to 10 seconds were allowed between changes in gun type.

5. Figure A-5 contains an aerial and plan view of the Rifle and Pistol Ranges showing the location of the shooters with lines connecting the shooter locations to receiver Locations R1, R2, and R3 where the acoustical measurements were made.

6. The exact times at which the shots were fired were noted by the Consultant stationed at the Range. The meters were synchronized and the sound level of the shots were identified in the data by comparing the times at which the shots occurred and the time on the meter, in addition to the notes taken by the Consultants at the receiver positions.

Measurement Results

1. Table B-3 in Appendix B contains a tabular summary of the Rifle and Pistol Range Study sound level data. Where shots were inaudible and/or not identifiable in the data, the cell is marked with a "-----". The table shows that sounds from the Rifle and Pistol Range were only audible and identifiable in the data at receiver Location R1.

2. Graphs of the 100-msec measurements made during the Trap and Skeet Range Study are included in Appendix C for each receiver location. The periods of time when the guns were fired from each range (25-Yard, 50-Yard, and 100-Yard x 2) are shaded on the graphs.

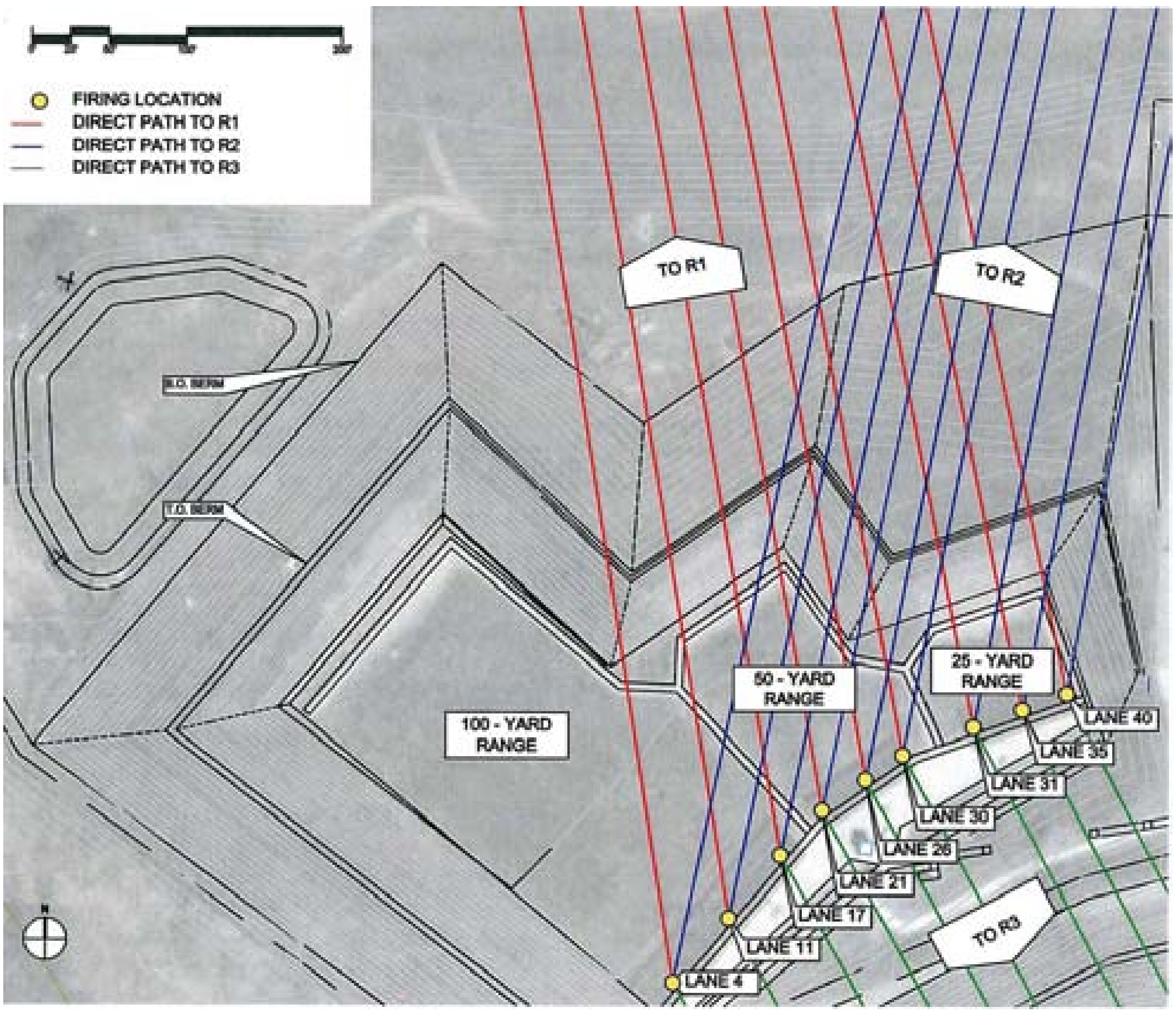

Figure A-5. Aerial map and plan of the Rifle and Pistol Ranges showing the shooter locations and the direct path for sound to the three residential receiver locations.

<u>Location R1</u>

1. The ambient sound level at Location R1 at that time of the Rifle and Pistol Range Study was generally in the 38 to 45 dBA range, with occasional increases in sound to as high as 50 dBA. Identifiable sounds consisted primarily of birds chirping, distant traffic sound, horses whinnying, wind in the trees, and distant construction sound.

2. At Location R1, which is north/northeast of the Ranges, gunshots from the 50-Yard Range were the loudest (46 to 62 dBA), followed by the 100-Yard Range (46 to 57 dBA) and then the 25-Yard Range (46 to 55 dBA).

3. The .308 Semi-Automatic Rifle and 12 Gauge Shotgun sounds from the 25-Yard Rifle and Pistol Range were plainly audible at Location R1, with sound levels measured in the 47 to 55 dBA range. The .308 Bolt-Action Rifle and the .223 Semi-Automatic Rifle were not heard and could not be identified in the data at Location R1 due to elevated ambient sounds at the time. The .40 Caliber Handgun sounds were not heard at Location R1 and could not be identified in the data.

4. All firearms fired on the 50-Yard Rifle and Pistol Range were plainly audible at Location R1, with sound levels measured in the 46 dBA (quietest Handguns) to 62 dBA (.308 Semi-Automatic Rifle) range. For the .308 Semi-Automatic Rifle, the sound level measured at Location R2 when the shooter was in Lane 21 (west end) was approximately 5 dB higher than when they were in Lane 30 (east end). The position of the shooter did not seem to have a significant effect for the other firearms.

5. Sounds from firearms fired on the 100-Yard Rifle and Pistol Range were measured in the 46 to 57 dBA range at Location R1. Occasional gunshots from the .223 Semi-Automatic Rifle, the 12 Gauge Shotgun, and the .40 Caliber Handgun were not audible in the presence of the 42 to 45 dBA background sound. Additionally, there was as much as a 6 dB difference in the sound level of the .308 Semi-Automatic Rifle measured at Location R2 between the first set of 100-Yard Rifle and Pistol Range measurements and the second set for the shooter located in Lane 4.

<u>Location R2</u>

1. The ambient sound level at Location R2 at that time of the Rifle and Pistol Range Study was generally in the 39 to 45 dBA range. Identifiable sounds consisted primarily of birds chirping, distant traffic sound, wind in the trees, and distant construction sound.

2. Two of the 22 shots from the 25-yard Rifle and Pistol Range were faintly audible at Location R2, but not identifiable in the data.

3. Three of the 22 shots from the 50-yard Rifle and Pistol Range were faintly audible at Location R2, but not identifiable in the data. The ambient sound level at Location R2 at that time was 39 to 45 dBA, consisting primarily of birds, distant traffic sound, wind in the trees, and distant construction sound.

4. All 22 of the shots from the 100-Yard Rifle and Pistol Range were faintly audible at Location R2 when they were known to be occurring, however they were not identifiable in the data. The ambient sound level at that time at Location R2 was 39 to 45 dBA, consisting primarily of birds, distant traffic sound, wind in the trees, and distant construction sound.

<u>Location R3</u>

1. The ambient sound level at Location R2 at that time of the Rifle and Pistol Range Study was generally in the 35 to 45 dBA range. Identifiable sounds consisted primarily of birds chirping, cars passing on Dixboro Road, planes passing overhead, and sheep bleating.

2. Sounds from the Rifle and Pistol Ranges were not audible at Location R3 in the presence of the ambient sound, nor could they be identified in the measurement data.

Findings/Conclusions

1. Sounds from the Rifle and Pistol Ranges were greater at Location R1 than at R2 and R3 due to the directionality of sound emitted from the firearms. Location R1 is less off-axis to the northeast than Location R2, and location R3 is behind the shooters where the sound levels are the lowest.

2. At Location R1, sounds from the 50-Yard and 100-Yard Ranges were louder than those from the 25-Yard Range primarily due to the greater distance between the shooters and the nearest berm. Berms are more effective when located closer to the source.

3. The data show that during the relatively neutral atmospheric conditions that occurred at the time of the measurements, sounds from firearms fired on the Ranges were plainly audible at Location R1 at levels that typically exceeded the ambient sound level by 5 to 10 dB, and occasionally by as much as 12 to 17 dB, depending on the type of gun used and the Range in which it was fired. This would typically be perceived as two to three times louder than the ambient by people with normal hearing sensitivities. Under acoustically adverse atmospheric conditions, these sounds could increase by as much as 10 dB or more.

4. Given the presence of the already large (24 ft high) berms around the Ranges, solutions that include upgrades to the overhead baffle system, partial enclosures around the shooters, or increased berm height will have effects that are limited to approximately 1 to 4 dB. This may provide relief for residents in the vicinity of Locations R1 and R2 from some of the quieter sounds during days when the weather conditions are acoustically "neutral" or advantageous, such as in the summer afternoons during a temperature lapse. To reduce the louder sounds during neutral weather conditions or all sounds during acoustically adverse weather conditions to the vicinity of the ambient sound levels at receiver locations to the north, a full building enclosure would be required.

4. Several large scale sound reduction options were modeled for the Ranges, including overhead baffles for the entire ranges and increased berm/barrier wall height. These schemes would be very costly (the barrier wall at $600,000 for material only, for example), and would provide no greater than a 1 to 4 dB reduction in sounds under acoustically neutral atmospheric conditions. Under

acoustically adverse weather conditions, such as temperature inversions, low lying cloud cover, or wind in the direction of sound travel, no reduction is anticipated.

Recommendations

1. As stated above, to reduce the louder sounds during neutral weather conditions or all sounds during acoustically adverse weather conditions to the vicinity of the ambient sound levels at receiver locations to the north, a full building enclosure with solid walls, roof, etc., over each of the ranges would be required. This solution will reduce the sound levels under any weather condition to the vicinity of the ambient sound levels in the surrounding residential neighborhoods. The cost of such a structure is beyond our ability to estimate at this time, but would likely be at least several million dollars, not including the lifetime costs to operate.

2. If this cannot be accomplished, a relatively low cost solution that may result in a 2 to 4 dB reduction in the source sound level, which may be a noticeable reduction in sound level, would be to construct solid walls consisting of a layer of 3/4" plywood on wood framing between the shooters for the full length of the existing Overhead Baffle System in the direction of gunfire, installing a layer of 3/4" plywood or other similar material, with roofing material and additional structural support as required, over the top of the existing system to close up all of the gaps between the baffles, and lining all of the walls and underside of the ceiling with 2" thick sound absorbing material to reduce the build-up of sounds inside the enclosure. Concept elevation and section sketches of this option are included in Figures A-6 and A-7. Sound absorbent material such as 2" thick semi rigid Porous Expanded Polypropylene (P.E.P.P.) Panels such as Acoustical Resources' Sound Silencer panels should be installed on the plywood surfaces to reduce sound reflections from gunshots to the extent possible. We recommend mocking up this solution in one or two lanes in the 50-Yard Range and conducting acoustical field measurements to quantify the performance due to uncertainties. The Michigan Department of Natural Resources should determine if inserting a solid wall between the shooters creates a safety issue that may preclude its use.

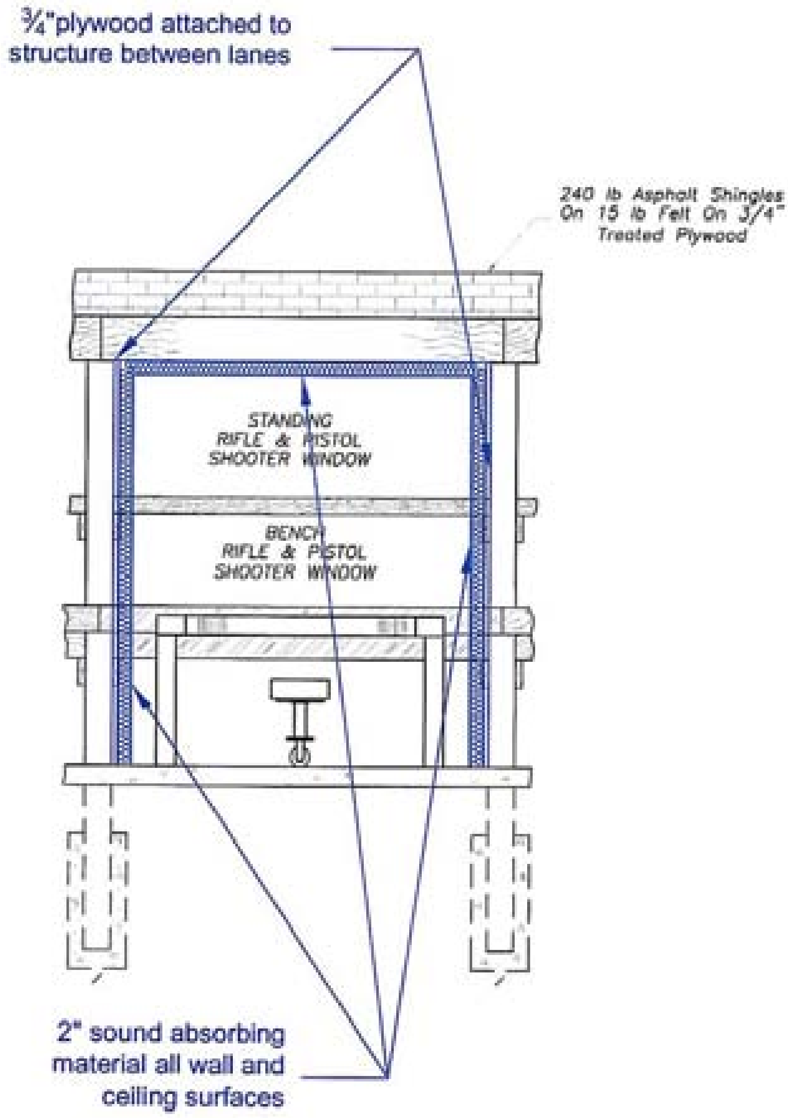

Figure A-6. Concept rear elevation sketch of a typical shooting lane with recommend sound barrier material.

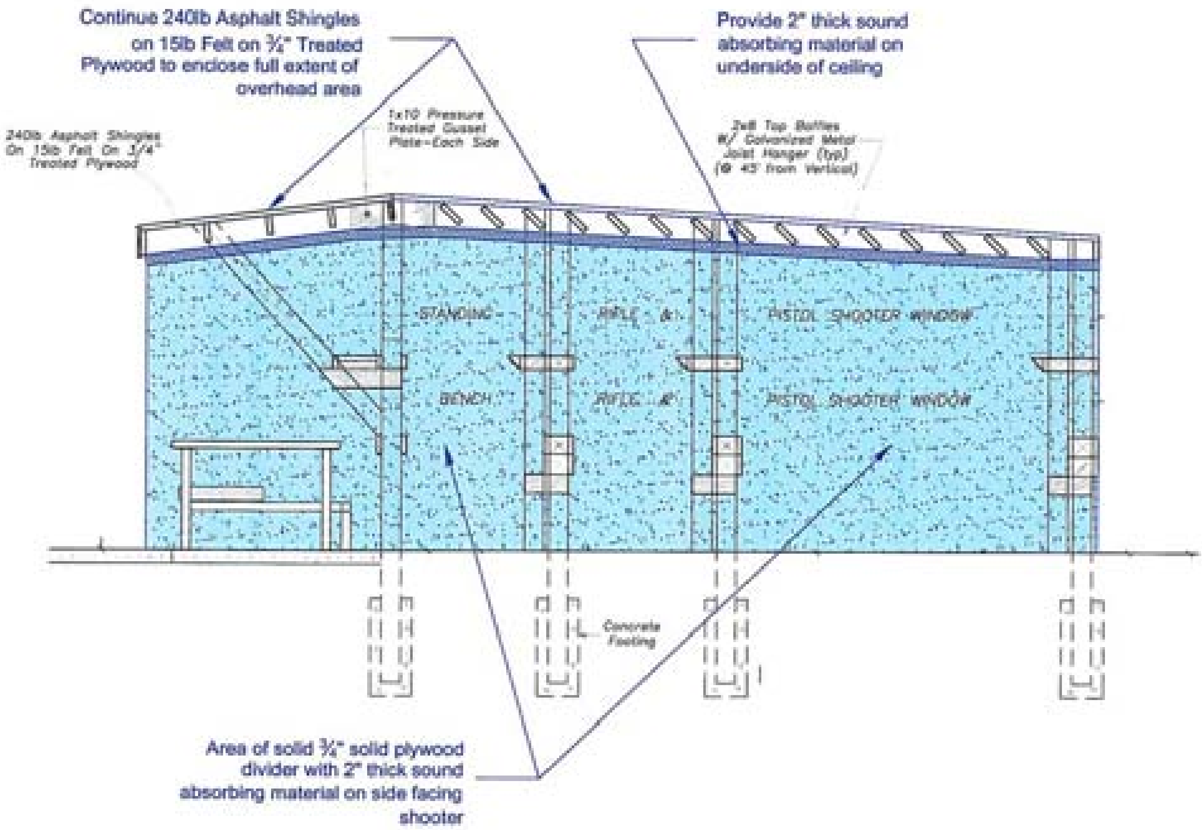

Figure A-7. Concept section sketch through a typical shooting lane with recommend sound barrier material.

COMPETITION DAY STUDY

Method

1. At Locations R1, R2, R3 and R4, short term acoustical measurements were made on June 21, 2008 of the range during a Tournament held at the Sporting Clay Range and Trap and Skeet Range, with the Rifle and Pistol Range under usage typical of a weekend day, to determine the magnitude and intensity of gunshot sounds at the receiver locations.

2. Times when gunshots were heard were noted by the consultants at the receiver locations. The level of the gunshots were determined by comparison of the times in which the shots arrived at the remote receiver locations with the times of arrival on the on-site meter (R4).

3. At Locations R5, R6, and R7, 1-minute average sound levels were taken for an entire 24-hour period that encompassed the entire day of range activities including the Tournament to compare with long term sound levels measured throughout the previous week during normal range usage. Please refer to Appendix D for graphs of level vs. time data from these measurements.

Measurement Results

1. Appendix C (Pages C-18 through C-21) contains the graphs of the short term acoustical measurements made during a 30-minute period in the afternoon during the Tournament at Location R1, R2, R3, and R4. Sound levels of gunshots measured at location R3 to the southeast of the site were in the 60 to 70 dBA range with several gunshots as high as 75 dBA. This is approximately 10 to 15 dB higher than the majority of sounds measured during the controlled studies. The notes taken by the Consultant at this time and location indicated an increase in winds from the north and increase in humidity and decrease in temperature as a brief rain had recently ended. This is likely the primary factor contributing to the increased sound levels at Location R3 compared to those measured during the controlled studies. Greater powder loads (3-1/4 drams versus 2-3/4 drams) and possible simultaneous gunshots adding together may also be a contributing factors.

2. The graphs containing long term measurements of sound levels measured at Locations R5, R6, and R7 during the competition show a greater difference between the 1-minute A-weighted maximum sound level (LAmax) and 1-minute average sound level (LAeq) than occurs during days of normal range usage. However, the 24-hour LDN for the competition day is the same or lower than LDNs for any previous day measured at these locations. This may be due to the reduced traffic on a Saturday that would offset any increases associated with the increased range activities. Additionally, the short term gunshots are more readily identified by the LAmax value in the graphs. The LAeq values are used to calculate the LDN metric. A summary of the LDNs from the long term measurements is included in the main body of the report.

SHOTGUN DIRECTIONALITY EXPERIMENT

Method

1. Acoustical measurements were made of a single shooter at a single position in an open field. All receiver positions were located at a distance of 75 feet from the shooter at multiple angles as described below. Receiver 1 was positioned 17 degrees off axis of the line of fire. This receiver was used as the reference position. Receiver 2 was positioned 45 degrees off axis, Receiver 3 was positioned 90 degrees off axis, Receiver 4 was positioned 135 degrees off axis, and Receiver 5 was positioned 180 degrees off axis (behind the shooter) to determine the directionality of the sound.

2. The shooter was using a 12 Gauge Shotgun with a 1 oz, 7-1/2 shot, 2-3/4" long, 2.75 dram Estate Super Sport Competition Target Load. Two shots were fired at each receiver position. The firearm was aimed at a single point, and held parallel to the ground for all shots fired.

3. Please refer to Figure A-8 for a drawing showing the Shooter and Receiver positions and the difference in sound level from the reference position for each receiver location.

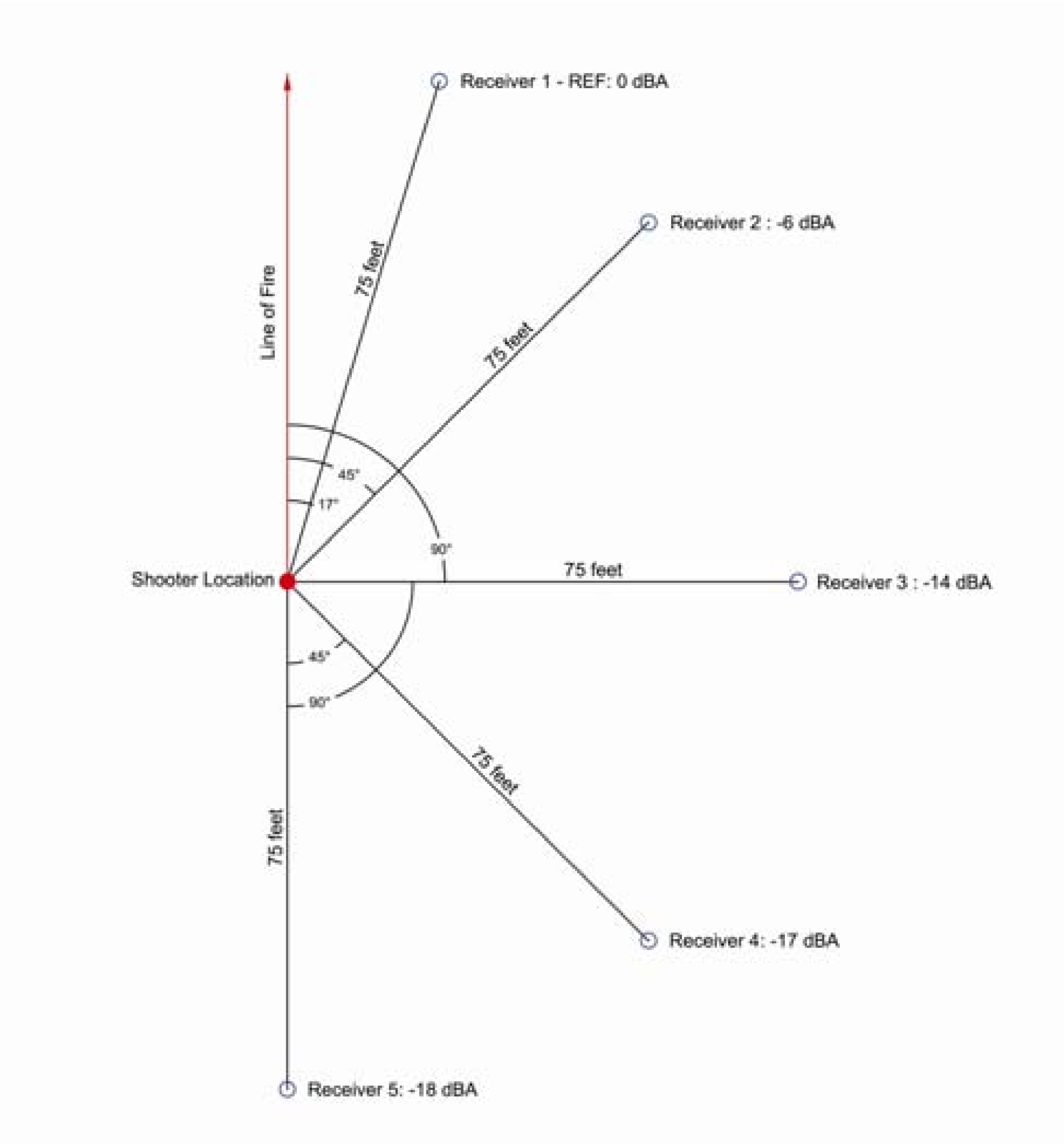

Figure A-8. Drawing showing the shooter and receiver locations for the Shotgun Directionality Experiment.

Results

1. Sound levels to the rear of the shotgun are 17 to 18 dB less than to the front.

2. Sound levels to the side of the shotgun are 14 dB less than to the front.

3. These differences of 14 to 18 dB account for more reduction in sound from the gunshots than any other possible sound reduction strategy with the exception of a full building enclosure, and demonstrates the importance of facing the guns away from potential residential receivers.

SPORTING CLAY SHED INSERTION LOSS EXPERIMENT

Method

1. Acoustical measurements were made of a single shooter located in a Sporting Clay Shed. All receiver positions were located at a distance of 75 feet from the shooter at multiple angles as described below. Receiver 1 was positioned 17 degrees off axis of the line of fire. This receiver was used as the reference position. Receiver 2 was positioned 45 degrees off axis, Receiver 3 was positioned 90 degrees off axis, Receiver 4 was positioned 135 degrees off axis, and Receiver 5 was positioned 180 degrees off axis (behind the shooter) to determine the directionality of the sound.

2. The shooter was using a 12 Gauge Shotgun with a 1 oz, 7-1/2 shot, 2-3/4" long, 2.75 dram Estate Super Sport Competition Target Load. Two shots were fired at each receiver position, approximately 3 seconds apart. The firearm was aimed at a single point directly in line with the centerline axis of the shed, and held parallel to the ground for all shots fired.

3. The data from the shed tests were compared to sound levels measured in the Shotgun Directionality Experiment, which were taken at the same distances and angles in open field conditions using the same shotgun and target loads, to determine the directional insertion loss provided by the sheds. Additional shots were fired outside adjacent to the shed, and inside the shed and sound level measurements were taken at a distance of 450 feet at 180 degrees off axis from the line of fire and at 135 degrees off axis from the line of fire.

Results

1. Please refer to Figure A-9 for a drawing showing the shooter and receiver positions relative to the shed enclosure, the sound levels from shots fired in open field conditions, the sound level of shots fired from inside the Sporting Clay Shed, and the resulting Insertion Loss at multiple angles from the line of fire.

2. The total difference between gunshot measurements made in front of the shooter and behind the shooter when inside the shed was 36 dB (18 dB for direction and 18 dB for insertion loss). This explains why only sounds from gunshots aimed in the general direction of receiver Locations R1, R2, and R3 were audible and identifiable in the data.

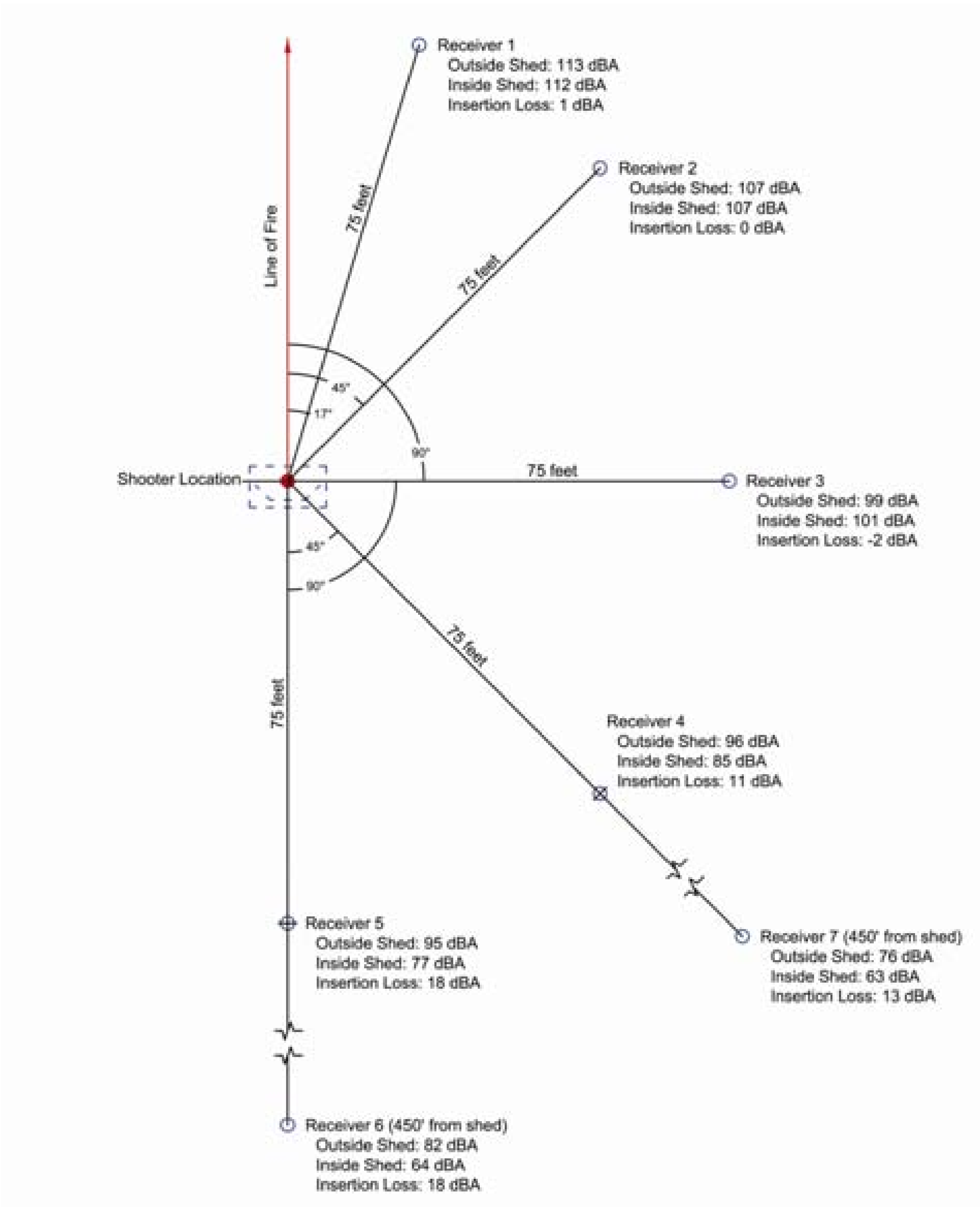

Figure A-9. Drawing showing the shooter and receiver locations for the Sporting Clay Shed Insertion Loss Experiment.

RIFLE AND PISTOL RANGE OVERHEAD BAFFLE INSERTION LOSS EXPERIMENT

Test Method

1. Acoustic field measurements were taken of shots fired inside and outside of the overhead baffle system at the 50-Yard Rifle and Pistol Range. Acoustical measurements were made using a CESVA SC310 real time sound analyzer. The meter was set to record both overall and octave band data.

2. Sound level measurements were taken on axis with the shooter, at 45 degrees off axis, at 90 degrees off axis, and at 180 degrees off axis behind the shooter as shown in Figure A-10. Locations were selected to provide safe positioning from gunshots, and adequate distance to be outside the acoustic shadow provided by the earthen berms. Sound levels of shots fired under the overhang were compared to sound levels of shots fired outside the overhang to determine the insertion loss provided by the overhang and the overall directionality of the sounds from the Rifle Range.

Measurement Results

1. The 1-second A-weighted average sound pressure level and octave band sound level data for shots fired under the overhang, and outside of the overhang at each position are presented below in Table A-2. Also shown is the Insertion Loss, which is the difference in sound levels attributable to the presence of the overhead baffle system.

2. Sound levels measured at locations R1 and R2 were buried in the high ambient sound levels from traffic on the nearby interstate and therefore are not presented. Sound levels measured at locations R3 indicate that high frequency sounds above 1 kHz are reduced somewhat by the overhead baffle system. At location R4 sound levels are increased by the baffle system due to reflections off the angled overhead baffles redirecting sound to the rear of the shooter.

Table A-2. Sound levels of shots fired under overhang, outside of overhang, and the resulting insertion loss provided by the overhang.

		1-second LAeq	Octave Band Center Frequency (Hz)							
Receiver Position	**Shooter Position**	**dBA**	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
R3 - 90 degrees off axis	Under Overhang	60	67	64	57	52	56	54	46	33
	Outside Overhang	66	62	60	55	57	63	59	53	46
	Insertion Loss	**6**	**-5**	**-4**	**-2**	**5**	**8**	**5**	**7**	**13**
R4 - 180 degrees off axis (behind shooter)	Under Overhang	86	71	73	76	83	81	80	73	64
	Outside Overhang	80	66	67	65	74	75	75	72	63
	Insertion Loss	**-5**	**-5**	**-6**	**-11**	**-9**	**-6**	**-5**	**-2**	**-1**

Figure A-10. Locations of shooter and receiver positions.

Conclusions

1. Due to the small size of the baffles in the overhead baffle system, the insertion loss in the direction of gunfire is not anticipated to be more than 1 to 3 dB at 500 Hz, which is the primary frequency from the guns experienced at distant receiver locations.

2. The insertion loss of the overhead baffle system was higher to the side of the shooter because the shooter was positioned in the middle lane and the baffle system essentially becomes much longer as the sound projects more to the side than downrange.

3. Acoustical improvements to the baffle system should include a solid roof over the entire system, vertical baffles between shooting lanes, and sound absorbing materials on all interior surfaces of the ceiling and lane dividers as described in the Recommendations portion of the Rifle and Pistol Range Study section. The Michigan Department of Natural Resources should determine if inserting a solid wall between the shooters creates a safety issue that may preclude its use.